DECLARATION

I, Yoshitaro Nobuta of c/o SHIGA INTERNATIONAL PATENT OFFICE, 2-3-1 Yaesu, Chuo-ku, Tokyo 104-8453 JAPAN, understand both English and Japanese, am the translator of the English document attached, and do hereby declare and state that the attached English document contains an accurate translation of the official certified copy of Japanese Patent Application No. 11-266203 and that all statements made herein are true to the best of my knowledge.

Declared in Tokyo, Japan

This eighteenth day of October, 2005

Yoshitaro Nobuta

(Yoshitaro Nobuta)

PATENT OFFICE
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this office.

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Information on Applicant

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[Document Type] SPECIFICATION

[Title of the Invention] SEMICONDUCTOR INTEGRATED CIRCUIT

[Claims]

[Claim 1] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate, wherein at least one hole is formed in said signal line.

[Claim 2] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate, wherein at least one hole is formed in said ground plate.

[Claim 3] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 2, wherein the size of said at least one hole formed in said ground plate is determined such that (1) the AC coupling between the signal line and another signal line disposed close to the signal line and on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission line and said ground plate is increased as much as possible.

[Claim 4] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 2 or 3, wherein the number of said at least one hole formed in said ground plate is determined such that (1) the AC coupling between the signal line and another signal line disposed close to the signal line and on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission line and said ground plate is increased as much as possible.

[Claim 5] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate, wherein at least one hole is formed in both of said signal line and said ground plate.

[Claim 6] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 5, wherein the size of said at least one hole formed in said ground plate among the signal line and the ground plate is determined such that (1) the AC coupling between the signal line and another signal line disposed close to the signal line and on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission

line and said ground plate is increased as much as possible.

[Claim 7] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 5 or 6, wherein the number of said at least one hole formed in said ground plate among holes formed in both of the signal line and the ground plate is determined such that (1) the AC coupling between the signal line and another signal line disposed close to the signal line on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission line and said ground plate is increased as much as possible.

[Claim 8] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to any one of claims 2 through 7, wherein said at least one hole in said ground plate is formed at a position where (1) the other signal line is not disposed or (2) said at least one hole in said ground plate is made small so as to reduce the AC coupling with one signal line when formed at a position where the other signal line is disposed.

[Claim 9] A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to any one of claims 1 through 8, wherein, instead of at least one hole formed in said signal line or in said ground plate, a plurality of slit holes are formed by forming said signal line or said ground plate of a plurality of thin strips and by connecting these thin strips at those terminal ends.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a semiconductor integrated circuit, provided with an improved characteristic impedance of the signal transmission line of a semiconductor integrated circuit, capable of reducing coupling with other signal lines.

[0002]

[Background Art]

Conventionally, when providing a signal transmission line with a microstrip structure constituted by a signal line and a ground plate in a semiconductor integrated circuit, two separate wiring layers for the signal line and for the ground plate are used as shown in Fig. 8.

In order to increase the characteristic impedance of this signal transmission line in a signal transmission line of a microstrip structure composed of the integrated signal lines and a

ground plate, two methods have been adopted, one method is to make the signal line width w narrower, and the other method is to increase the distance d between the signal line and the ground plate.

Furthermore, the other conventional technique is disclosed in Japanese Unexamined Patent Application, No. Hei 5-343564, which sets the characteristic impedance of the transmission line to a predetermined value by a mesh-like mesh ground plane, and the spaces corresponding to the pores of the mesh ground plane are compensated for by the ground plate.

[0003]

[Problem to be Solved by the Invention]

However, when the above-described first method for making the signal line width narrower is adopted, the problem arises that it is difficult to form a connection path (a via) between wiring layers because the maximum input capacitance of a circuit connected to the end of the signal transmission line becomes small.

When the above-described second method of increasing the distance between the signal line and the ground plane is adopted, the problem is encountered that the thickness or the number of wiring layers increases, because it is necessary to increase the thickness of the interlayer films of the wiring layers or to increase the number of wiring layers by using, for example, a ground wire as the first layer wire and a signal line as the third layer wire.

[0004]

When the third method disclosed in Japanese Unexamined Patent Application, First Publication No. Hei 5-343564 is adopted, although it is possible to increase the impedance of the signal line, the problem arises that, when assembling into an integrated circuit, since the signal lines cannot be formed under the ground plane, it is not possible to avoid generating coupling between a plurality of signal lines.

When coupling occurs, a deficiency arises in that the characteristic impedance of a certain signal line will experience a dynamic change, because the capacitance between one signal line and its counter line changes when the voltage level of the counter signal line changes.

In addition, the problem also arises in the case of using a mesh ground plane that it is difficult to evaluate the characteristic impedance, since the electro-magnetic field distribution generated through small holes or spaces cannot be accurately understood.

[0005]

This invention has been made under such circumstances. It is, therefore, an objective of the present invention to provide a semiconductor integrated circuit, capable of reducing the coupling between a plurality of signal lines and increasing the characteristic impedance of the signal transmission line of a microstrip structure, which can be realized in a semiconductor device by forming holes in the signal lines or the ground plate.

[0006]

[Means for Solving the Problem]

The invention as recited in claim 1 is a semiconductor integrated circuit comprises a signal transmission line of a microstrip structure composed of a signal line and a ground plate, wherein at least one hole is formed in said signal line.

[0007]

According to the invention as recited in claim 2, in a semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate, at least one hole is formed in said ground plate.

[0008]

According to the invention as recited in claim 3, in a semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 2, the size of said at least one hole formed in said ground plate is determined such that (1) the AC coupling between the signal line and another signal line disposed close to one signal line and on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission line and said ground plate is increased as much as possible.

[0009]

According to the invention as recited in claim 4, in a semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 2 or 3, the number of said at least one hole formed in said ground plate is determined such that (1) the AC coupling between one signal line and another signal line disposed close to one signal line and on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission line and said ground plate is increased as much as possible.

[0010]

According to the invention as recited in claim 5, in a semiconductor integrated circuit

comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate, at least one hole is formed in both of said signal line and said ground plate.

[0011]

According to the invention as recited in claim 6, in a semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 5, the size of said at least one hole formed in said ground plate among the signal line and the ground plate is determined such that (1) the AC coupling between one signal line and another signal line disposed close to one signal line and on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission line and said ground plate is increased as much as possible.

[0012]

According to the invention as recited in claim 7, in a semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to claim 5 or 6, the number of said at least one hole formed in said ground plate among holes formed in both of the signal line and the ground plate is determined such that (1) the AC coupling between one signal line and another signal line disposed close to one signal line and on the opposite side of said ground plate is decreased as much as possible and (2) the characteristic impedance of said signal transmission line and said ground plate is increased as much as possible.

[0013]

According to the invention as recited in claim 8, in a semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to any one of claims 2 through 7, said at least one hole in said ground plate is formed at a position where (1) the other signal line is not disposed or (2) said at least one hole in said ground plate is made small so as to reduce the AC coupling with one signal line when formed at a position where the other signal line is disposed.

[0014]

According to the invention as recited in claim 9, in a semiconductor integrated circuit comprising a signal transmission line of a microstrip structure composed of a signal line and a ground plate according to any one of claims 1 through 8, where, instead of at least one hole formed in said signal line or in said ground plate, a plurality of slit holes are formed by forming said signal line or said ground plate of a plurality of thin strips and by connecting these thin

strips at those terminal ends.

[0015]

[Modes for Carrying Out the Invention]

Hereinafter, the first through third embodiments of the present invention will be described with reference to the drawings.

[0016]

<First Embodiment>

Fig. 1 is a diagram showing the structure of the semiconductor integrated circuit according to the first embodiment of the present invention.

As shown in Fig. 1, in the signal transmission line of the microstrip structure realized in a semiconductor integrated circuit according to the present embodiment, at least one hole 13 (normally, a plurality of holes 13) is formed on a signal line of a transmission line composed of a signal line 11 and a ground plate 12.

In a signal transmission line of the microstrip structure, the characteristic impedance Z is expressed by the equation,

$$Z = (L/C)^{1/2}$$

where C represents the inter-wiring capacitance per unit length, and L represents the inductance of the wiring.

[0017]

The provision of a hole (or a plurality of holes) 13 in the signal line 11 lengthen the electric force line generated between the signal line 11 and the ground plate 12 and the distance between the signal line 11 and the ground plate 12 is apparently elongated equivalently, which results in a decrease of the inter-wiring capacitance C.

When the velocity of the electro-magnetic wave is represented by v, the velocity v is constant and is expressed by the following equation.

$$v = 1/ (LC)^{1/2}$$

Thus, when the capacitance C decreases, the wiring inductance L increases.

Consequently, the characteristic impedance can be increased by forming one or more holes in the signal line.

In addition, the increase of the characteristic impedance as shown above makes it possible to suppress the reduction of the maximum input capacitance of the circuit connected at the end of the transmission line, and the increase of the characteristic impedance does not

require an increase in the number of wiring layers.

[0018]

The size of the hole 13 in the signal line 11 shown in Fig. 1 can be determined as follows. The size of the hole is determined so as to reduce the wiring resistance of the signal line 11 as much as possible. At the same time, the size of the hole is determined so as to sufficiently increase the characteristic impedance between the signal line 11 and the ground plate 12 as much as possible.

[0019]

The number of holes 13 in the signal line 11 shown in Fig. 1 may be determined so as to fulfill the following conditions. The number can be decreased to reduce the wiring resistance of the signal line 11 as much as possible, and the number can be increased to increase the characteristic impedance between the signal line 11 and the ground plate 12 as much as possible.

[0020]

It is noted that, instead of forming the holes in one signal line 11, the signal line 11 may be formed by a plurality of signal line strips spaced apart from each other by slits and the plurality of signal line strips are connected at a certain portion such as both termination ends for forming a plurality of slit-like holes.

[0021]

<Second Embodiment>

Fig. 2 is a diagram showing the structure of the semiconductor integrated circuit according to the second embodiment of the present invention.

As shown in Fig. 2, in the signal transmission line of the microstrip structure realized in a semiconductor integrated circuit according to the second embodiment, at least one hole 23 (normally, a plurality of holes 23) is formed on the ground plate 22 of a transmission line composed of a signal line 21 and a ground plate 22.

In the signal transmission line of the microstrip structure, the characteristic impedance Z is expressed by the equation,

$$Z = (L/C)^{1/2}$$

where C represents the inter-wiring capacitance per unit length, and L represents the inductance of the wiring.

[0022]

The provision of a hole (or a plurality of holes) 23 in the ground plate 22 lengthen the electric force line generated between the signal line 21 and the ground plate 22 and the distance between the signal line and the ground plate is apparently elongated equivalently, which results in a decrease of the inter-wiring capacitance C.

When the velocity of an electro-magnetic wave is represented by v, the velocity v is constant and is expressed by the following equation.

$v = 1/(LC)^{1/2}$

Thus, when the capacitance C decreases, the wiring inductance L increases.

Consequently, the characteristic impedance can be increased by forming one or more holes in the ground plate 22.

As described above, it becomes possible to suppress the reduction of the maximum input capacitance of the circuit connected at the end of the transmission line, and it is not necessary to increase the number of wiring layers.

[0023]

The size of the hole 23 in the ground plate 22 shown in Fig. 2 can be determined as follows. The size of the hole is determined to reduce the AC coupling between two signal lines 21 adjacent to each other above the hole 23 in the ground plate 22 as much as possible. At the same time, the size of the hole is determined to sufficiently increase the characteristic impedance between the signal line 21 and the ground plate 22 as much as possible.

[0024]

The number of holes 23 in the ground plate 22 shown in Fig. 2 can be determined so as to fulfill the following conditions. The number can be decreased to reduce the AC coupling between two signal lines 21 adjacent to each other above hole 23 in the ground plate 22 as much as possible, and the number of the holes is determined to increase the characteristic impedance between the signal line 21 and the ground plate 22 as much as possible.

[0025]

It is noted that, instead of forming the holes in the ground plate 22, the ground plate 22 may be formed by a plurality of ground plates spaced apart from each other by slits and the plurality of ground plates are connected at a certain portion such as both termination ends for forming a plurality of slit-like holes.

[0026]

Next, the magnitude of the coupling and the characteristic impedance are explained

based on the results of simulations in the case of forming the ground plate 22 by a plurality of ground plates, separated by slit-like spaces, with reference to Figs. 3 to 6.

Fig. 3 (a) is a cross-sectional view of one transmission line comprising one signal line 21 of 1.2 μ m in width and 0.6 μ m in thickness, and a ground plate 22, divided into two plates, each having a width of 50 μ m, by a single slit of width w, wherein the ground plate is located spaced by a distance d from the signal line. Fig. 3 (b) is a cross-sectional view of a transmission line comprising the signal line 21 and a ground plate divided into four parts, having a width of 25 μ m, by three slits, each having a width of w/3, and these four parts are separated by three slits, wherein the ground plate is separated from the signal line 21 by a distance of 0.6 μ m.

[0027]

Fig. 4 is a schematic diagram showing the capacitance between one signal line 21 and a ground plate 22, and the other signal line 23. It is assumed that the capacitance between the signal line 21 and the ground plate 22 is represented by Cg, and the capacitance between the signal line 21 and the other signal line 23 is represented by C_{13}.

[0028]

Fig. 5 is a diagram showing the relationship between the total slit width of the ground plate and a value of C_{13}/Cg shown in Fig. 4, wherein three lines are shown, in which the dashed line shows the case that the ground plate 22 is divided by a single slit and the distance d between the ground plate and the signal line is 0.6 μ m, the dashed and dotted line shows the case that the ground plate 22 is divided by a single slit and the distance d between the ground plate and the signal line is 1.8 μ m, and the solid line shows the case that the ground plate is divided into four parts and the distance d between the ground plate and the signal line is 0.6 μ m. It is noted that the value of C_{13}/Cg represents the magnitude of the coupling between one signal line 21 with the other signal line 23.

In Fig. 5, when an allowable value of the coupling between the signal line 21 and the other signal line 23 is assumed to be $C_{12}/Cg = 0.2$, the total slit widths of the ground plate in the respective cases must be restricted to within 3 μ m, 4.5 μ m, and 9 μ m or less, and the total slit width cannot exceed these values.

[0029]

As can be understood from Fig. 6, the characteristic impedance increases according as

the slit width is increased. In addition, with respect to the length of the slit which is formed in the longitudinal direction, although the characteristic impedance increases according as the slit is elongated, there is a demerit in that the wiring resistance increases because a wiring area is reduced.

[0030]

<Third Embodiment>

Fig. 7 is a diagram showing the structure of a semiconductor integrated circuit according to the third embodiment of the present invention.

As shown in Fig. 7, in the signal transmission line of the microstrip structure realized in a semiconductor integrated circuit according to the present embodiment, at least one hole 33 (normally, a plurality of holes 33) is formed on the signal line 31 and the ground plate 32 of the transmission line composed of the signal line 31 and the ground plate 32.

In a signal transmission line of the microstrip structure, the characteristic impedance Z is expressed by the equation,

$$Z = (L/C)^{1/2}$$

where, C represents the inter-wiring capacitance at an unit length, and L represents the inductance of the wiring.

[0031]

The provision of a hole (or a plurality of holes) 33 in both of the signal line 31 and the ground plate 32 lengthen the electric force line generated between the signal line 31 and the ground plate 32 and the distance between the signal line 31 and the ground plate 32 is apparently elongated equivalently, which results in a decrease of the inter-wiring capacitance C.

When the velocity of an electro-magnetic wave is represented by v, the velocity v is a constant and is expressed by the following equation.

$$v = 1/(LC)^{1/2}$$

Thus, when the capacitance C decreases, the wiring inductance L increases.

That is, the characteristic impedance can be increased by forming one or more holes in the signal line and the ground plate.

Consequently, it becomes possible to suppress the reduction of the maximum input capacitance of the circuit connected at the end of the transmission line, and it is not necessary to increase the number of wiring layers.

[0032]

The size of the hole 33 in the ground plate 32 shown in Fig. 7 can be determined as follows. The size of the hole is determined to reduce the AC coupling between two adjacent signal lines 31 on the hole 33 in the ground plate 32 as much as possible, and the size of the hole is determined to increase the characteristic impedance between the signal line 31 and the ground plate 32 as much as possible.

[0033]

The number of holes 33 in the ground plate 32 shown in Fig. 7 is determined so as to reduce the AC coupling between two signal lines 31 adjacent on the hole 33 in the ground plate 32 as much as possible, and so as to increase the characteristic impedance between the signal line 31 and the ground plate 32 as much as possible.

[0034]

The size of the hole 33 in the signal line 31 shown in Fig. 7 can be determined as follows. The size of the hole is determined so as to reduce the wiring resistance of the signal line 13 as much as possible. At the same time, the size of the hole is determined so as to sufficiently increase the characteristic impedance between the signal line 13 and the ground plate 32 as much as possible.

[0035]

The number of holes 33 in the signal line 31 shown in Fig. 7 may be determined so as to fulfill the following conditions. The number can be decreased to reduce the wiring resistance of the signal line 31 as much as possible, and the number can be increased to increase the characteristic impedance between the signal line 31 and the ground plate 32 as much as possible.

[0036]

It is noted that it may be possible, instead of forming holes in the signal line and the ground plate, to constitute the signal transmission line by forming the signal line 31 and the ground plate 32 by a plurality of strips, and by connecting these strips at, for example, both termination ends of these strips so as to provide a plurality of slit-like holes between each of these strips.

[0037]

The present invention was described above in detail by explaining the first to the third embodiments. However, the present invention is not limited to these three embodiments described above, but variants thereof can be envisaged without exceeding the scope of the

present invention.

For example, the present invention includes the case of both of the signal line and the ground plate having holes together with slits.

Furthermore, in the above embodiments, one signal line is disposed on the ground plates. However, the ground plate may be disposed on the signal line, and the ground plate may occupy the most significant position. Such a disposition allows the ground plate to exhibit a shielding effect. In this case, the ground plate may be formed simultaneously with the formation of the bonding pads on the passivation film, which simplifies the manufacturing process.

[0038]

[Effects of the Invention]

As described above, in a signal transmission line of a microstrip structure composed of the signal line and the ground plate, the present invention shows a notable effect in that the capacitance between wiring can be decreased and the characteristic impedance between the signal line and the ground plate can be increased by forming holes in the signal line or in the ground plate.

The other effect of the present invention is that the coupling between one signal line with another signal line through the ground plate can be reduced by forming holes in the ground plate.

[Brief Description of the Drawings]

[FIG. 1] Fig. 1 is a diagram showing the structure of the signal transmission line according to the first embodiment of the present invention.

[FIG. 2] Fig. 2 is a diagram showing the structure of the signal transmission line according to the second embodiment of the present invention.

[FIG. 3] Fig. 3 is a diagram showing the relationship between signal lines and a ground line provided with a single slit.

[FIG. 4] Fig. 4 is a diagram showing the relationship between signal lines and a ground line provided with the slit divided into three slits.

[FIG. 5] Fig. 5 is a graph showing the relationship between the slit width in the ground plate and magnitude of the coupling.

[FIG. 6] Fig. 6 is a graph showing the slit width in the ground plate and the characteristic impedance.

[FIG. 7] Fig. 7 is a diagram showing the structure of a signal transmission line according to the third embodiment of the present invention.

[FIG. 8] Fig. 8 is a diagram showing the structure of a conventional signal transmission line.

[Brief Description of the Reference Symbols]

11, 21, and 31	signal line
12, 22, 32, and 42	ground plate
13, 24, 33, and 34	hole
23 and 35	other signal line
41	signal line

[Document Type] ABSTRACT

[Abstract]

[Problem to be Solved by the Invention]

A semiconductor integrated circuit comprising a signal transmission line of a microstrip structure, capable of increasing the characteristic impedance of the signal transmission line and reducing coupling between a plurality of signal lines.

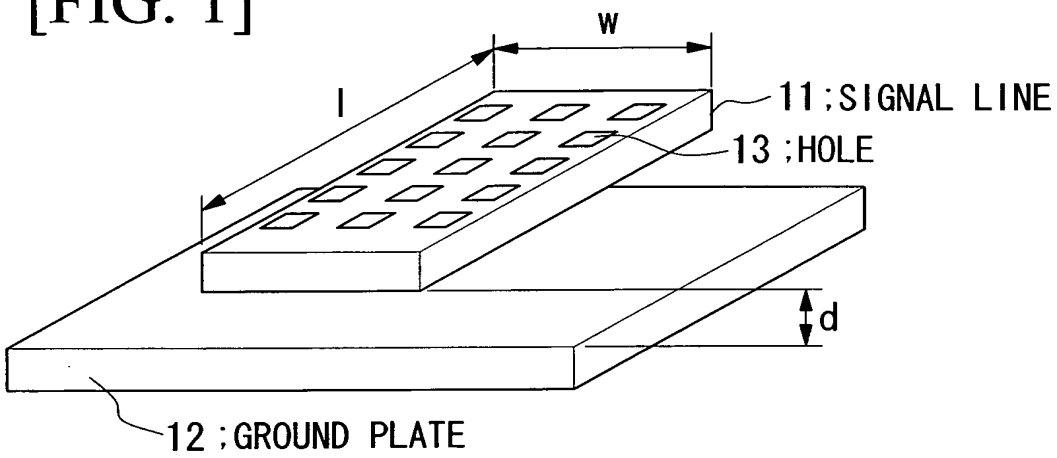
[Means for Solving the Problem]

In a signal transmission line of a microstrip structure composed of a signal line and a ground plate, the capacitance between wires is reduced and the characteristic impedance can be increased by forming holes in the signal line or in the ground plate. The coupling between a plurality of signal lines can also be reduced.

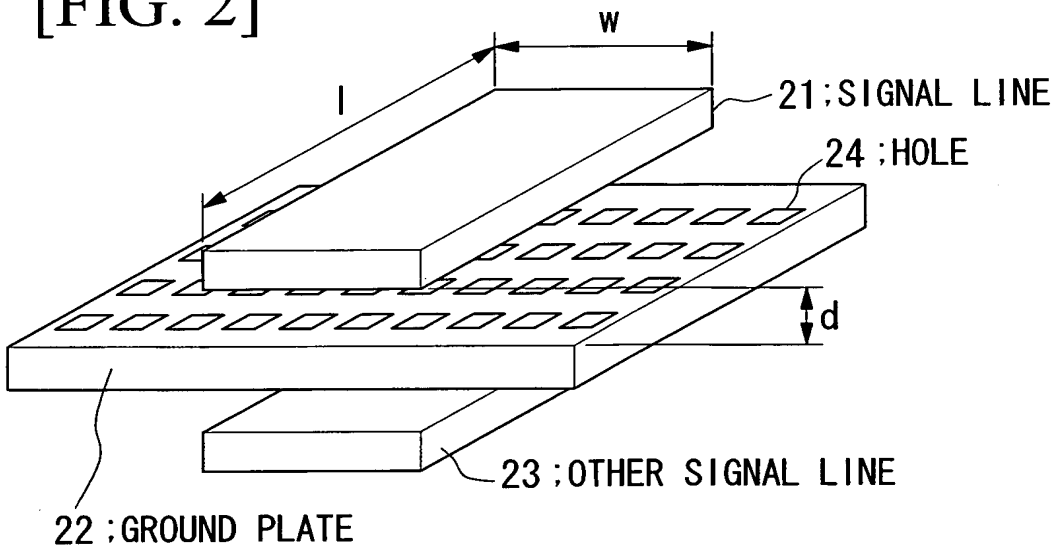
[Elected Drawing] FIG. 2

[Document Type] Drawing

[FIG. 1]

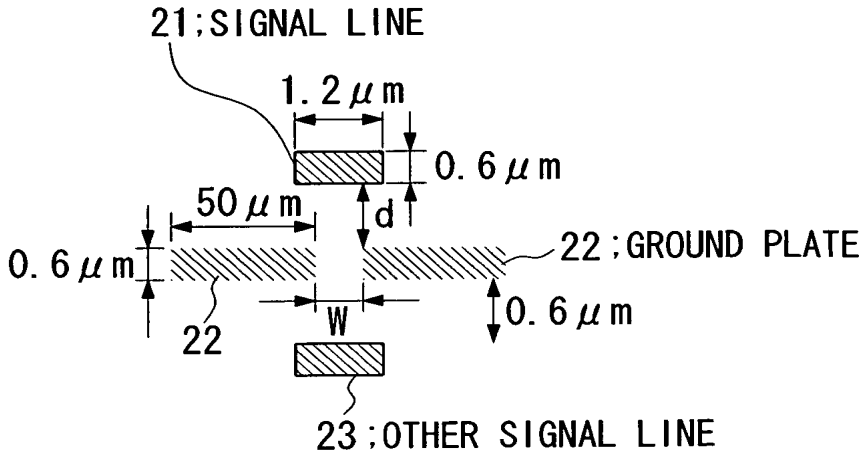


[FIG. 2]



[FIG. 3]

(a)



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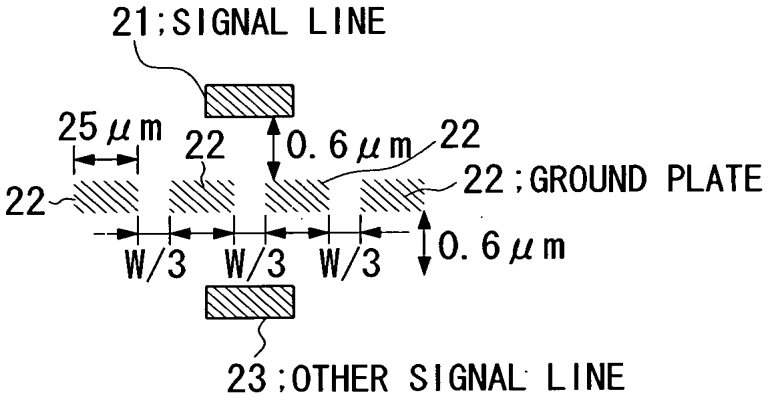
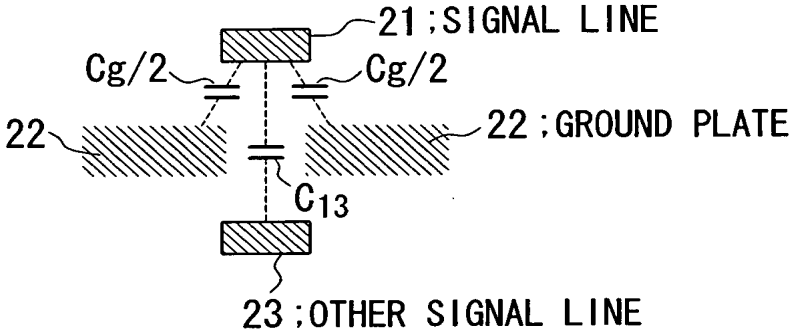
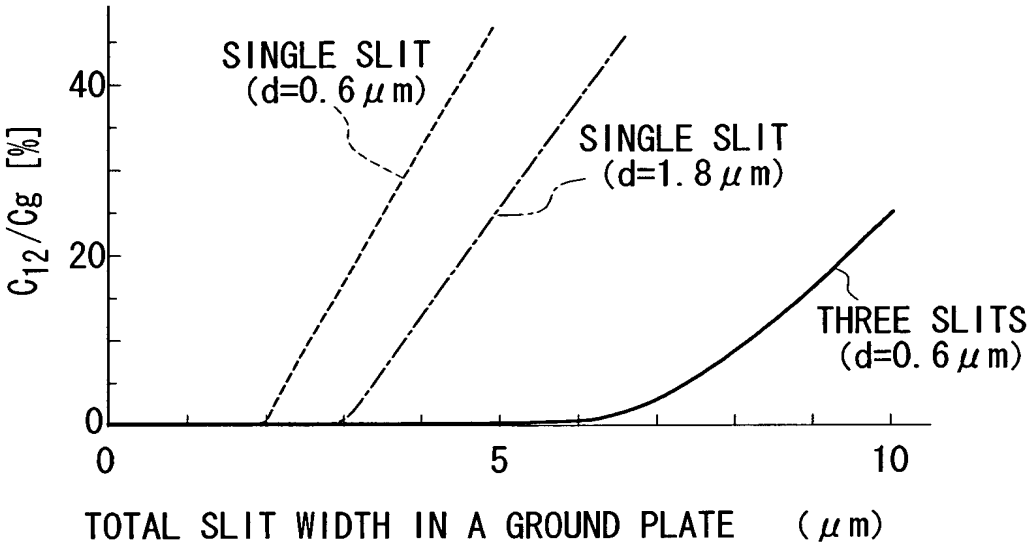


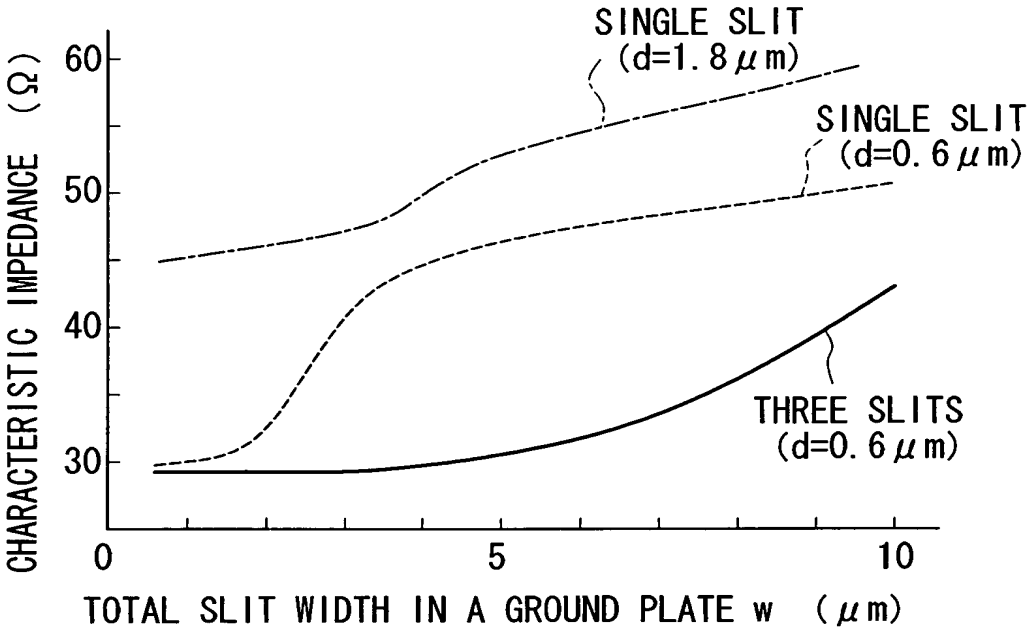
[FIG. 4]



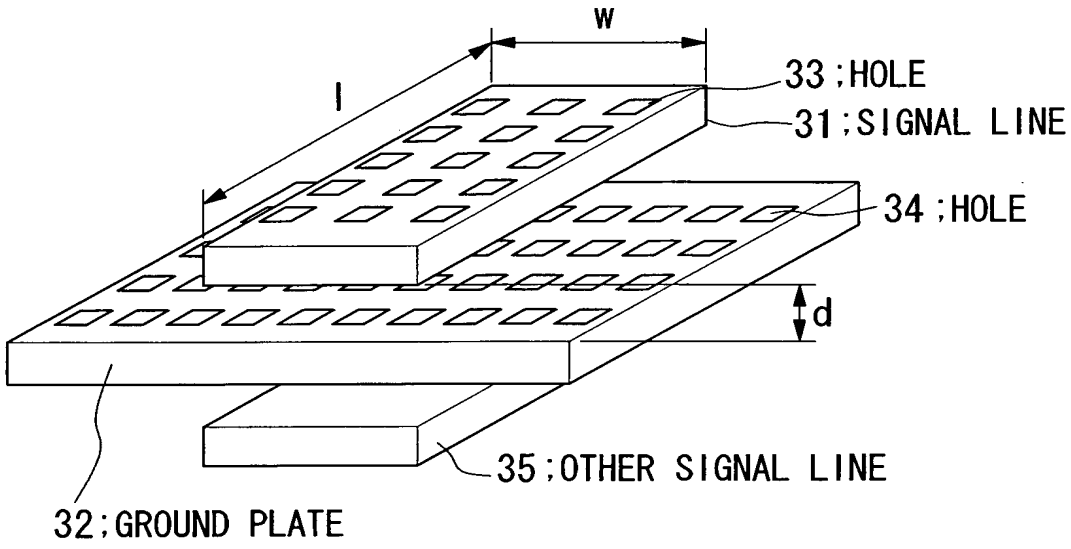
[FIG. 5]



[FIG. 6]



[FIG. 7]



[FIG. 8]